REPEATING RADIO FREQUENCY TRANSMISSION SYSTEM FOR EXTENDING THE EFFECTIVE OPERATIONAL RANGE OF AN INFRARED REMOTE CONTROL SYSTEM.

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FIELD OF THE INVENTION

The present invention relates to a method and a system of extending the effective operating range and selectivity of an infrared remote control system of the type used with audio and video equipment.

BACKGROUND OF THE INVENTION

One of the pervasive features of consumer audio and video electronic components in recent years has been and continues to be the handheld remote control. The handheld remote control sends control signals to the controlled device by irradiating the device with infrared energy generated by infrared photo emitter diodes. The controlled device receives a pattern of intermittent irradiation or illumination comprising a control signal.

The remote control unit has stored patterns corresponding to push buttons assigned to various functions of the controlled device. Activating a button causes the excitation of the photo emitter diode according to the stored pattern, thereby generating and transmitting a control signal. Control signals tend to be short words of data representing a low order numeric signal corresponding to some function of the controlled electronic appliance. Conventionally, infrared (IR) remote control units use a carrier frequency of between 10 kHz and 75 kHz. The controlled device receives the signal with a photo detection diode and circuitry that interprets as logical lows and highs the alternating illumination of the photo emitter diode on the remote control unit. Such a signal corresponds to the pattern stored in the remote control unit.

Various manufacturers have selected unique numeric codes to control their devices. This unique coding has allowed differentiation between such devices. For instance, a Brand X VCR will have a limited vocabulary of signals that influence its action. The Brand Y television will have a different limited vocabulary of signals. If a signal is not present within a device's vocabulary, the device will do nothing. With several devices, each having a distinct and limited vocabulary, a single universal remote control can control all of them, distinctly.

While infrared transmission of control signals is an inexpensive and reliable means of controlling one or more devices, it suffers from several shortcomings. The remote control unit transmits much as a flashlight illuminates. All transmissions propagate strictly along lines of sight. If walls, enclosures, furniture, or people block the path between the remote control unit and the controlled device, the controlled signal is occluded and the device cannot respond. A VCR in a cabinet enclosure will not respond.

Further, as in an auditorium or restaurant, if several of the same brand and model of device are present, a single signal might affect a plurality of those devices present. As only those of the units that the remote control unit illuminates by the emission of its photo emitter diode will receive the signal, the number of units that respond may not always be uniform or predictable.

In United States Patent Number 4,809,359, issued February 28, 1989, and 5,142,397, issued August 25, 1992, the inventor Dockery teaches a system for extending the range of an infrared remote control system. The system comprises two units known as repeaters. The first repeater receives the infrared control signal from the handheld remote control unit and translates that signal to a corresponding UHF radio frequency signal. The second repeater, located remotely from the first and adjacent to the controlled device, receives the UHF signal and reconstitutes it into an infrared control signal equal to that the handheld remote control unit sent to the first repeater. The controlled device then receives it and responds just as it would to the handheld remote control unit.

The advantage to the Dockery system is that it teaches a signal that will pass through obstructions. The handheld remote control and first repeater of the Dockery patent can control a VCR and second repeater entirely enclosed within a cabinet or even

in a second room. Such a system of repeaters allows for a home entertainment system that is inconspicuous within a room or a centrally wired programming center that is remote from the television unit.

The Dockery teaching has several disadvantages however. Principal among those disadvantages is the lack of selectivity. The infrared remote control device will transmit only within a single room and within that room only to those devices illuminated by the photo emitter diode. The first repeater in Dockery's patent, on the other hand, will transmit through walls and other structures. In a home, apartment building, or other area with multiple repeater sets present, one first repeater can be in signal communication with several of the second repeater units. This "crosstalk" between signal units may result in the unintended control of several controlled devices, especially devices outside of the presence of the viewer or listener.

SUMMARY OF THE INVENTION

The instant invention provides a system and a method of addressably transmitting RF control signals to an addressed receiver for controlling IR controlled devices. Rather than to simply transmit an unqualified signal interpretable by all receivers in signal proximity to the transmitter apparatus, as with the Dockery system, the instant invention embeds an address into the RF signal within the transmitter apparatus. Only those receiver apparatuses that recognize the embedded address within the signal will respond.

The system of the present invention comprises a transmitter that receives the infrared control signal from the handheld remote control unit and converts that signal into an electronic or digital signal, adds an address to that signal, and converts that signal into an RF signal. A receiver receives the RF signal and examines the signal for the presence

of the address; if the address is present, it strips the address from the signal; converts that signal to an infrared control signal, and transmits the infrared control signal to the controlled device. The transmitted infrared control signal thus mimics that initially received by the transmitter unit.

The transmitter includes a photo detector diode that receives infrared control signals from the handheld remote control unit supplied with the controlled device. Several configurations of the transmitter will serve the inventive purposes of this invention. In one embodiment, the transmitter mounts on the handheld remote control unit in a manner that places the photo detector diode in close proximity and signal communication with the IR transmitting diode on the handheld remote control. The transmitter alternately may stand-alone but be in close proximity to the viewer or listener as they operate the handheld remote control, aiming it at the stand-alone device.

In yet another configuration, the transmitter is able to "learn" infrared control signals in the manner taught by Tigwell in United States Patent 5,277,780. In such a configuration, the viewer or listener programs the transmitter unit by placing that unit in close proximity to the handheld remote control. The viewer or listener then selectively activates functions of the handheld remote control unit while the transmitter is in a receptive state to "learn" the corresponding function. The received IR signal is then stored in association with that function within the transmitter. When the viewer or listener then wishes to activate that function on the controlled device, the viewer or listener activates the corresponding buttons on the transmitter unit. The transmitter then treats the stored signal associated with the function as though the transmitter had just received the control signal.

Still further, an RF remote is provided to send the RF signals to a receiver in proximity with the controlled device. The receiver then converts the received RF signals into IR signals that are understood by the controlled device.

Once the transmitter receives an infrared control signal, it stores that signal in electronic form in a buffer. The transmitter then augments the signal with a stored digital signal that serves to identify the transmitter or controlled device. In its augmented form, the transmitter sends the RF signal to the RF receiver. The transmitter might have one or a plurality of stored digital identification signals. Where a plurality exists, the viewer or listener may actively select the identification signal to augment the stored control signal.

The receiver remains in a constant receptive state. When the receiver receives any radio frequency signal, it examines that signal for the presence of the digital identification signal stored within the receiver apparatus. Once the receiver receives that signal and recognizes the stored identification code, the receiver strips the code from the signal; converts the rest of the signal to an IR signal, and transmits that IR signal to the controlled device.

In accordance with further aspects of the invention, the invention differentiates the intended receiver from a plurality of receiver apparatuses, each of which has an identification code distinct from that stored in the intended receiver. These aspects of the invention allow its non-interactive operation in an environment filled by a plurality of transmitter apparatus/receiver pairs.

In accordance with other aspects of the invention, two remote receiver apparatuses with the same stored identification code would control distinct devices in locations remote from each other. For example, a single operator might have a satellite receiver

feeding programs to several television sets in several rooms. The operator can control the satellite receiver at each of the television sites using one receiver to control the television and a second receiver to control the remotely located satellite receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiment of the present invention is described in detail below with reference to the following drawings.

FIGURE 1 is a diagram of the inventive aspects of the internal circuitry of the claimed apparatus;

FIGURE 2 depicts the various methods used to modulate IR control signals in commercially available controlled devices;

FIGURE 3 is a drawing of an embodiment of the claimed apparatus in two units, including a transmitter and a receiver;

FIGURE 4 is a flowchart depicting a preferred method for transmitting and receiving an addressed signal;

FIGURE 5 depicts a preferred installation of the transmitting unit onto a standard remote control;

FIGURE 6 depicts a receiver in communicative interaction with two possible controlled electronic devices;

FIGURE 7 portrays the use of a plurality of the inventive devices demonstrating the non-interfering use;

FIGURE 8 portrays an alternate embodiment of the inventive device depicting the use of a single transmitter used to independently control a plurality of receivers; and,

FIGURE 9 portrays an alternate embodiment of the inventive device depicting the programming of the transmitter with a handheld IR remote control.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings in detail, and particularly to Figure 1, the inventive aspects of the circuitry are described. According to one presently preferred embodiment, the invention comprises two distinct units: the transmitter **100,** and the receiver **200**. In this embodiment, the receiver **200** is placed adjacent to the controlled device or devices (for example, a television or VCR) to allow the photo emitter diode **270** and is in signal communication with the IR receiver of the controlled device. Similarly, the transmitter **100** is placed adjacent to the handheld IR remote control unit and is in signal communication with it. The range between the transmitter **100** and the receiver **200** may vary as a function of a variety of factors such as the frequency and power of the transmitter **100**.

An IR photo detector diode **110** is the input device for the invention. The photo detector diode **110** receives a serial bit control signal **50** from the handheld remote control unit, generally an infrared control signal with a carrier frequency of between 10 and 75 kHz. Of course, any frequency range may be used consistent with this invention. Commercially available IR remote control units use several modulation schemes to encode IR commands to the controlled device. Because IR transmission characteristics vary greatly in intensity from the center of the beam to the edges, no practical modulations scheme will use amplitude modulation to define control signals.

The photo detector diode **110** acts as its own demodulator in any IR communications application. Infrared radiation is that class of electromagnetic radiation

with a frequency of between 10^{12} and 10^{14} Hz. The photo detector diode **110** will only trigger in the presence of infrared radiation and, when triggered, passes a constant current. The latency of the diode smoothes adjacent sampled highs into a single pulse. Thus, the signal from the photo detector diode **110** amplified by the amplifier **120** to logical levels requires no further demodulation.

The presence of an incoming control signal triggers a signal detector **150** which sends a logical high to the multiplexor **160**. Contemporaneously, the signal loads the First In First Out ("FIFO") buffer **130**, where the buffer delays all or a portion of the signal just long enough to place an identification code stored within the code register **140** at the beginning of the control signal. The identification code might be stored at the code register **140** by any of several means. For instance, Dual In-Line Package ("DIP") switches can carry the code, as can EPROM chips, Flash ROM, or an array of digital latches. Often code registers may be registers within a micro-controller rather than discrete integrated circuits. These alternatives allow the transmitter **100** to be constructed with a single stored code or, alternatively, to allow the user to set the code from among a range of possibilities.

Thus, with each cycle of instruction sensed by the IR Photo Diode **110**, the multiplexor **160** allows the annunciation of the stored identification code in the code register **140** and then draws the signal from the FIFO buffer, completing the augmented control signal. The multiplexor **160** then conveys the augmented control signal to an RF transmitter **170** for radiation through the antenna.

The augmented control signal is a digital signal. To transmit the augmented control signal, the transmitter **100** must impress that control signal onto a carrier signal of

any suitable frequency. The augmented control signal passes through a modulator **170** for modulation. Modulation schemes for radio frequency ("RF") transmission of a digital signal use the carrier signal as a pulse train rather than to convey all of the additional information in a continuous analog stream. Any suitable scheme for transmission will use some form of pulsed carrier such as square pulses, or raised cosine pulses, or sync function (Nyquist) pulses.

The RF transmitter **180** is low-power radio systems commercially available from any of a number of manufacturers such as RF Monolithics, Inc., which typically transmit less than 1 milliwatt of power and operate over distances of 5 to 100 meters. In the case of chips from RF Monolithics, Inc., the modulator **180** is located on the chip. Thus, a digital signal input to the chip produces a modulated RF signal at the antenna. "On chip" modulation is not necessary for the invention. Because the science of radio transmission is well known, a manufacturer may readily use discrete components for modulation and demodulation of the RF signal. The transmitter is selected from such RF products as are certified to comply with local low-power communications regulations such that these systems do not require a license or "air time fee" for operation. At this point, the signal leaves the transmitter **100** through an antenna **190**.

At an antenna **210**, the augmented RF control signal enters the receiver **200**. The antenna **210** conveys that augmented control signal to the RF receiver **220** selected from any of the compatible receivers from any of the same manufacturers that supplied the RF transmitter. As in the case of the transmitter, demodulation of the RF augmented control signal can occur on the chip where such chips are available, otherwise, demodulation occurs at a demodulator **230**. In addition, as in the RF transmitter, a particular

demodulation scheme is not necessary so long as the scheme matches the modulation scheme at the transmitter **100**. From the RF receiver **220** and demodulator **230**, an amplifier **235** boosts the voltage of the augmented signal to digital logic levels. A code detector **250** analyzes the inbound augmented control signal from the amplifier **230** and compares the code at the leading edge of the augmented control signal with that stored in a second code register **240**, where an identification code is stored. If the code detector **250** determines that the received code is the same as the stored code, it sends a gating logical high to the multiplexor **260** that blanks that portion of the augmented control signal corresponding to the code and allows the remainder of the augmented control signal **60** to pass to the infrared photo diode emitter **270**. As reconstructed, the remainder of the augmented control signal **60** should mimic the inbound control signal **50** at the transmitter. The infrared photo diode emitter **270** is in signal proximity to the infrared sensor on the TV, VCR, or other controlled device. The circuitry diagram shows one infrared photo diode emitter **270** for simplicity. Alternatively, a plurality of such photo diodes can be included to allow for the control of a plurality of such devices from a single transmitter **100** and receiver **200** pair.

FIGURE 2 displays the several modulation schemes consumer electronics manufacturers exploit to effect remote control. FIGURE 2a displays the simplest modulation scheme, the fixed-bit-time/full-width-burst. It is the analog to one-bit serial communication across a wire. A leading zero, however, will not trigger a response in the controlled unit. For this reason, rather than a simple on- or off-state, short bursts represent a zero and long bursts a one in the fixed-bit-time/modulated-burst-width as shown in FIGURE 2b. To compress signals in time, the off time is made constant in the

fixed-off-time-burst/width-modulated mode portrayed in FIGURE 2c. Another variant on the fixed-bit-modulation scheme has either one or two narrow bursts to represent zero or one respectively, the fixed-bit-time/single-burst/double-burst modulation shown in FIGURE 2d. This same scheme is compressed using a fixed off time as in the fixed off-time/single burst/double burst modulated scheme shown in FIGURE 2e. Rather than modulate the burst time, the off-time is modulated in the fixed-burst-time/off-time-modulated scheme portrayed in FIGURE 2f.

In each instance (FIGURES 2a-2f), there is a burst unit representative of the wavelength of the highest frequency digital signal present in the waveform, which is the building block of the digital signal. Shannon-Nyquist Sampling Theorem assures that sampling at a rate greater than twice the frequency of the highest frequency present in the control signal will assure the accurate capture of an IR control signal. As an example of this sampling, FIGURE 2g demonstrates the accuracy of the sampling of the fixed burst time off-time modulated signal.

Figure 3 portrays highly stylized depictions of the exterior of enclosures for the transmitter **100** and receiver **200**, along with the attendant photo diode emitters **270**. This Figure 3 is included to assist in the interpretation of subsequent figures showing the placement and use of the invention. The shape of the enclosures as portrayed is not intended to limit the invention in any way.

Figure 4 is a flow chart depicting a preferred embodiment of the invention as it processes the control signals emitted from the handheld remote control unit supplied with the controlled device and its transmission to the controlled device. The transmitter **100** waits in a receptive state **191** for an inbound IR control signal. The photo detector diode

110 is responsive to the infrared control signals from the handheld remote control unit supplied with the controlled device in this receptive state.

Upon receiving an infrared control signal **192**, the transmitter **100** converts the code to an electronic control signal, much as the controlled device would, in order to process the signal.

The receiver augments the infrared code signal by the addition of the programmed identification code **193**. Augmenting, in the instance of the preferred embodiment, means placing the programmed electronic identification code at the leading edge of the control signal. Alternatively, the identification code may be placed at the trailing edge or embedded within the control signal. The signal might even be encrypted by an algorithm using the identification code as a key along with a confirmatory header within the control signal. The augmenting might not be distinct from the modulation step **194**, for instance, the carrier frequency chosen by the transmitter may be a function of the programmed code in the code register **140**. Any means of concatenating or embedding the identification code within the control signal may be used.

Once the transmitter **100** augments the control signal, it converts that electronic control signal to an RF signal in a process known as modulation **194** for transmission to the receiver **200**. Generally, a transmitter **100** will transmit control codes over RF using UHF frequencies. The transmitter must impress the control code onto a carrier signal in the UHF band. Modulation may be by any of several means such as pulse width, serial data, pulse code, pulse position, or modulation by phase. Such modulation options are dictated by the choice of commercially available RF receivers and RF transmitters but no

particular modulation or frequency ranges are required. Once modulation **194** occurs, the signal is transmitted **195.**

The processing shifts to the receiver **200**. Like the transmitter **100**, the receiver **200** waits in a receptive state **291**. The RF receiver **220** is responsive to control signals at the transmitted frequency and modulated by the appropriate means. The signal is, then, demodulated, i.e., the augmented control signal is distilled from the RF augmented control signals received at the receiver **220** in a process that is the inverse of that selected to modulate the augmented control signal at **194.** After receiving and demodulating the signal, the receiver **200** checks the received signal for the presence of the identification code stored within the receiver **292**. Unless the identification code is present, the receiver **200** returns to a receptive state **291**. If the identification code is present, the receiver **200** treats the signal as an augmented control signal and then strips the code from the received augmented control signal **294**.

Once the receiver **200** strips the identification code from the augmented signal, the remaining control signal should mimic that received at step **192**. The receiver now at step **295** sends the control signal to the controlled electronic device by means of the photo emitter diode **270**.

Figure 5 depicts the transmitter **100** in the preferred embodiment as it is placed on a handheld remote control unit **10** supplied with a controlled device. Notable in this placement is the intentional occlusion and containment of the IR radiation from the handheld remote control unit's **10** photo diode emitter with respect to the controlled devices. This is a single embodiment. Alternate embodiments are possible. This placement of the transmitter achieves the important signal isolation of the handheld

remote unit from the controlled devices in order to prevent redundant instructions by alternate transmission paths through and around the inventive device. Another embodiment would allow placement of the transmitter in close signal proximity to the handheld device and the occlusion of the photo detection diode on the controlled device to all IR radiation except that from the photo emitter diode **270** on the receiver **200**. Such an embodiment might facilitate the placement of controlled devices in cabinetry that would normally prevent remote control of the devices by infrared means.

Figure 6 shows the receiver **200** in signal communication with one or alternately two controlled devices. In practice, a receiver **200** will typically have two IR emitters **270**—one, a high powered directional emitter and the other a wide angle to help to flood the room with IR signal energy (in fact, these receivers typically have more than two emitters to ensure that the room is flooded with IR signal energy). This redundancy is to insure that the positioning of the emitter in front of the equipment is not required. In addition, flooding the room with IR signal energy allows control of multiple devices with a single placement of the RF receiver. Figure 6 portrays the installation for stereo racks, where a string of IR emitters **270a 270b** on a cable allowing IR emitters **270a 270b** affixed close to the IR receiver on the equipment. As discussed in the preceding paragraph, any placement of the photo emitter diode **270** must be in IR signal communication with the controlled device.

Figure 7 depicts one of the advantages to the inventive system. If transmitter and receiver pairs **100**, **200** have distinct identification codes from other adjacent pairs, the inventive system can be operated without fear of interference. Thus, a signal from a first transmitter **101** will be received by each of the receivers **200**, **201**, and **202**. However,

only the receiver **200** that has stored within it the same identification code as the first transmitter **100**, will transmit a control signal to its controlled devices **71** and **81**. The other receivers **201**, **202** will disregard the received signal. This selectivity is not possible with the prior art transmitters.

Figure 8 depicts an alternate embodiment of the inventive device. In this embodiment, the transmitter **110** holds several identification codes. The user can designate a code through any of several means including a keypad, any form of switch, or by varying the input from the handheld remote control unit **10**. Alternatively, the user can select buttons designated as TV1, TV2, VCR1, VCR2, or others. Once the user designates that code, the corresponding receiver **100**, **101**, or **102**, as the case may be, responds to such control signals as the user may enter through the handheld remote control unit. This embodiment might be useful in auditoria, restaurants, or other such public halls where a plurality of controlled devices produced by the same manufacturer might be present. Without the instant invention, isolation of a single of these controlled devices for control would not be possible.

Figure 9 depicts an alternate embodiment of the inventive device. In this embodiment, rather than to require activation of a handheld IR remote control **10** to execute a command, the transmitter **105** "learns" the vocabulary of the controlled device. The transmitter is set to "learn" mode. The operator designates a command on the transmitter **105** and then activates the corresponding command on the handheld IR. Like the preferred embodiment, the transmitter receives the IR control signal at the photo detector diode **110** and stores the received IR control signal in memory associated with the designated command. Once all commands are "learned," the transmitter **105** is placed

in "use" mode. When the operator actuates a command on the transmitter **105**, the associated control signal is drawn from memory just as the preferred embodiment would draw the signal from the buffer **130**, and embeds the stored ID from the code register **140**. Transmission of the augmented control signal occurs just as in the preferred embodiment. The same RF receiver **200** receives the RF augmented control signal and activates the controlled device in the same manner as in the preferred embodiment.

A further embodiment of the invention includes a database with codes for all controlled devices commercially available. A look-up table associates all of the control commands with data signals for each available controlled device. The operator associates each of the several controlled devices with a different one of the several controlled device buttons available on the RF transmitter **105**. By associating a Brand X Model 10 television with the TV1 button, the operator has associated control signals with each function of the controlled device. When the operator actuates a controlled device button and then a command button on the transmitter **105**, the transmitter draws the associated control signal from memory just as the preferred embodiment would draw the signal from the buffer **130**, and embeds the stored ID signal from the code register **140**. All of the remaining functions are as in the preceding embodiments.

While the preferred embodiment of the invention has been illustrated and described, many changes can be made without departing from the spirit and scope of the invention. Accordingly, the scope of the invention is not limited by the disclosure of the preferred embodiment. Instead, the invention should be determined entirely by reference to the claims that follow.